PB83-182493

Analysis of ARB (Air Resources Board) Data for California Emission Factors

Technology Service Corp.
Santa Monica, CA

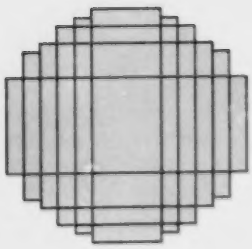
Prepared for

Environmental Protection Agency
Ann Arbor, MI

Aug 80

U.S. Department of Commerce
National Technical Information Service
NTIS

PB83-182493



REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

Technology Service Corporation

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO. PB83 182493
4. TITLE AND SUBTITLE: Analysis of ARB Data for California Emission Factors.		5. REPORT DATE: August 1980 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S): John Gins, Feorge Rakulijic, Nancy Chang, Michael Thiele		8. PERFORMING ORGANIZATION REPORT NO.: TSC-PD-A231-3
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Technology Service Corporation 2950 31st Street San Monica, California 90405		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO.: 68-03-2836 Task Number 2
12. SPONSORING AGENCY NAME AND ADDRESS: United States Environmental Protection Agency Office of Mobile Source Air Pollution Control Test and Evaluation Branch Ann Arbor, MI 48105		13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

The Office of Mobile Source Air Pollution Control within the Environmental Protection Agency has the responsibility to monitor emissions from in-use passenger vehicles in order to assess the impact of these emissions on air quality throughout the county. The mobile source emission estimation model, MOBILE2, (an updated version of MOBILE1) has, as a major component, emission factors which are ultimately used to assess the impact of mobile emissions on air quality. MOBILE2 can be used to assist the regions with the State Implementation Plans, the constructing of environmental impact statements, and setting up transportation control measures. Since California has different vehicle emission standards than the other 49 states, California is analyzed and reported on separately in MOBILE2.

The objective of this task order is to analyze emissions data gathered by the California Air Resources Board (CARB). This analysis will then be compared to the results of the California emission factors derived by the EPA from data gathered in Emission Factor Programs. Technology Service Corporation has defined model year group based on emission control technology and California emission standards. The state of California Air Resources Board data analysis will be based on these groups. Technology Service Corporation has also related by emission control technology the California groups with the 49-state model year groups already defined for MOBILE2. EPA will use this relationship to compare California and Federal emissions for (OVER)

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Air Quality Carbon Monoxide Exhaust Emissions Hydrocarbons Motor Vehicles Nitrogen Oxides	Trucks Emission Factors Mobile Source emissions model Computer Programming	California Air Resources Board (CARB) Technology Service Corp. Mobile2 Computer Program State	

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release Unlimited	unclassified	56
	20. SECURITY CLASS *(This page)* unclassified	22. PRICE

EPA Form 2220-1 (9-73)

vehicles with similar technologies.

Technology Service Corporation

2950 31st STREET • SANTA MONICA, CALIFORNIA 90405 • (213) 450-9755

ANALYSIS OF ARB DATA FOR CALIFORNIA EMISSION FACTORS

TSC-PD-A231-3

August 1980

John Gins
Nancy Chang
Michael Thiele
George Rakuljic

Draft Final Report

Contract No. 68-03-2836, Task No. 2

Submitted to:

U.S. ENVIRONMENTAL PROTECTION AGENCY
2565 Plymouth Road
Ann Arbor, Michigan 48105

Task Officer: Mr. Jay Wallace

CONTENTS

Section

1. INTRODUCTION..... 1

1.1 BACKGROUND..... 1
1.2 PURPOSE..... 1
1.3 REPORT LAYOUT..... 2
1.4 CONCLUSIONS..... 2

2. MATCHING CALIFORNIA MODEL YEAR GROUPS TO FEDERAL MODEL YEAR GROUPS..... 4

2.1 DEFINITION OF MODEL YEAR GROUPINGS..... 4
2.2 MATCHING MODEL YEAR GROUPS..... 20

3. HOMOGENEITY OF THE SIX ARB DATA SITES..... 21

3.1 VEHICLE SELECTION AND CVS-75 EMISSION TEST..... 21
3.2 COMBINED DATA SET..... 22

4. DATA VERIFICATION FOR CARB DATA SET..... 24

4.1 CARB REPORT NUMBER ONE..... 24
4.2 CARB REPORT NUMBER FOUR..... 24
4.3 CARB REPORT NUMBER SEVEN..... 26
4.4 CARB REPORT NUMBER EIGHT..... 27
4.5 CARB REPORT NUMBER ELEVEN..... 27
4.6 CARB REPORT NUMBER TWELVE..... 28

5. ANALYSIS..... 31

5.1 DATA BASE..... 31
5.2 DESCRIPTIVE STATISTICS OF THREE EMISSIONS UNDER EACH MODEL YEAR GROUP..... 31
5.3 REGRESSION ANALYSIS BETWEEN EMISSIONS AND ODOMETER READINGS..... 35

LIST OF TABLES

Table

2.1 Definition of Model Year Group for Light Duty Gasoline Vehicles for HC..... 5

2.2 Definition of Model Year Group for Light Duty Gasoline Vehicles for CO..... 6

2.3 Definition of Model Year Group for Light Duty Gasoline Vehicles for NO_x..... 7

2.4 Definition of Model Year Group for Light Duty Gasoline-Powered Trucks for HC..... 8

2.5 Definition of Model Year Group for Light Duty Gasoline-Powered Truck for CO..... 9

2.6 Definition of Model Year Group for Light Duty Gasoline-Powered Truck for NO_x..... 10

2.7 Definition of Model Year Group for Medium Duty Gasoline-Powered Truck for HC..... 11

2.8 Definition of Model Year Group for Medium Duty Gasoline-Powered Truck for CO..... 12

2.9 Definition of Model Year Group for Medium Duty Gasoline-Powered Truck for NO_x..... 13

2.10 Definition of Model Year Group for Heavy Duty Gasoline-Powered Vehicles..... 14

2.11 Definition of Model Year Group for Light Duty Diesel-Powered Vehicles..... 15

2.12 Definition of Model Year Group for Light Duty Diesel-Powered Truck 1..... 16

2.13 Definition of Model Year Group for Light Duty Diesel-Powered Truck 2..... 17

2.14 Definition of Model Year Group for Heavy Duty Diesel-Powered Vehicles..... 18

LIST OF TABLES (Continued)

Table

2.15 Definition of Model Year Group for Motorcycle..... 19

4.1 Summary of Changes Made During Data Verification..... 25

5.1 Breakdown of Model Year and Emission Control Device for Light Duty Vehicles..... 32

5.2 Breakdown of Model Year and Emission Control Device for Light Duty Trucks..... 33

5.3 Breakdown of Model Year for Medium Duty Trucks..... 34

5.4 Descriptive Statistics for California Light Duty Gasoline Vehicles' Hydrocarbon Emissions in Each Hydrocarbon Model Year Group..... 36

5.5 Descriptive Statistics for California Light Duty Gasoline Vehicles' Mileage in Each Hydrocarbon Model Year Group..... 37

5.6 Descriptive Statistics for California Light Duty Gasoline Vehicles' Carbon Monoxide Emissions in Each Carbon Monoxide Model Year Group..... 38

5.7 Descriptive Statistics for California Light Duty Gasoline Vehicles' Mileage in Each Carbon Monoxide Model Year Group..... 39

5.8 Descriptive Statistics for California Light Duty Vehicles' Oxides of Nitrogen Emissions in Each NO_x Model Year Group..... 40

5.9 Descriptive Statistics for California Light Duty Vehicles' Mileage in Each NO_x Model Year Group..... 41

5.10 Descriptive Statistics for California Light Duty Trucks for Each Hydrocarbon Model Year Group..... 42

5.11 Descriptive Statistics for California Light Duty Trucks in Each Carbon Monoxide Model Year Group..... 43

5.12 Descriptive Statistics for California Light Duty Trucks in Each Nitrogen Oxides Model Year Group..... 44

LIST OF TABLES (Continued)

Table

5.13 Descriptive Statistics of Hydrocarbon for California Medium Duty Truck in Each Model Year Group..... 45

5.14 Descriptive Statistics of Carbon Monoxide for California Medium Duty Truck in Each Model Year Group..... 46

5.15 Descriptive Statistics of Nitrogen Oxides for California Medium Duty Truck in Each Model Year Group..... 47

5.16 Descriptive Statistics of Odometer for California Medium Duty Truck in Each Model Year Group..... 48

5.17 Results of Regression Analysis on Hydrocarbon Emissions and Odometer for California Light-Duty Gasoline Vehicles..... 49

5.18 Results of Regression Analysis on Carbon Monoxide Emissions and Odometer for California Light-Duty Gasoline Vehicles..... 50

5.19 Results of Regression Analysis on Nitrogen Oxides Emissions for California Light-Duty Gasoline Vehicles..... 51

5.20 Results for Regression Analysis for Cal'fornia Light-Duty Gasoline-Powered Trucks..... 52

5.21 Regression Analysis Between Hydrocarbon and Odometer for California Medium-Duty Gasoline-Powered Trucks..... 53

5.22 Regression Analysis Between Carbon Monoxide and Odometer for California Medium-Duty Gasoline-Powered Trucks..... 54

5.23 Regression Analysis Between Nitrogen Oxides and Odometer for California Medium-Duty Gasoline-Powered Trucks..... 55

1. INTRODUCTION

This report summarizes Technology Service Corporation's (TSC) results of a review of emissions data gathered by the California Air Resources Board (CARB) and an analysis of California model year groups and Federal (the other 49 states) model year groups.

1.1 BACKGROUND

The Office of Mobile Source Air Pollution Control within the Environmental Protection Agency has the responsibility to monitor emissions from in-use passenger vehicles in order to assess the impact of these emissions on air quality throughout the county. The mobile source emission estimation model, MOBILE2, (an updated version of MOBILE1) has, as a major component, emission factors which are ultimately used to assess the impact of mobile emissions on air quality. MOBILE2 can be used to assist regions with the State Implementation Plans, the constructing of environmental impact statements, and setting up transportation control measures. Since California has different vehicle emission standards than the other 49 states, California is analyzed and reported on separately in MOBILE2.

1.2 PURPOSE

The objective of this task order is to analyze emissions data gathered by the CARB. This analysis will then be compared to the results of the California emission factors derived by the EPA from data gathered in Emission Factor Programs. TSC has defined model year group based on

emission control technology and California emission standards. The ARB data analysis will be based on these groups. TSC has also related by emission control technology the California groups with the 49-state model year groups already defined for MOBILE2. EPA will use this relationship to compare California and Federal emissions for vehicles with similar technologies.

1.3 REPORT LAYOUT

Chapter 2 presents the model year groups for the California vehicles and pairs them with Federal model year groups.

Chapter 3 presents the analysis of the comparability among the data bases given in six CARB reports.

Chapter 4 presents the changes that needed to be made to the data because of keypunching or coding errors.

Chapter 5 presents the analysis of emissions and odometer readings (mileage) for each model year grouping present in the data. Descriptive statistics are presented as well as a regression analysis between emissions and mileage.

1.4 CONCLUSIONS

There is not a perfect match between California and Federal model year groups because of differences in emission standards and control technology. However there is enough of a match that comparisons could be made.

The six data sets derived from the CARB reports can be combined after some duplicates are deleted. However while some of the individual reports

might be respresentative of the California vehicle fleet the combination would not be respresentative without a stratification of weighting procedure. There are no diesels in the data base.

The data sets contained minor keypunch and coding errors and emission control devices are not listed for a number of vehicles.

The data analysis by model year group indicate that for some model year groups ~~the~~ samples are just too small. The 1975 and 1976 model year light duty gasoline-powered vehicles are the most represented. The regression analysis indicates that use of a linear model to relate emissions with mileage is unreasonable for this data because either the percent of variation explained by using the model is too small or the coefficients are not significantly different from zero or because the sample was of an insificient size for regression analysis to be performed.

2. MATCHING CALIFORNIA MODEL YEAR GROUPS TO FEDERAL MODEL YEAR GROUPS

In order to study the difference in deterioration factors between California vehicles and federal vehicles it is necessary to know that the vehicles under comparison have the same types of emission control devices and must meet a similar emission standard.

2.1 DEFINITION OF MODEL YEAR GROUPINGS

Tables 2.1 through 2.10 give the definition of model year groups for gasoline powered vehicles and Tables 2.11 through 2.14 give the definition of model year groups for diesel fueled vehicles. Table 2.15 gives the definition for motorcycles.

The definitions are made by emissions and vehicle classes the emissions under consideration are total hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides (NO_x). The vehicle classes are light duty vehicle (LDGV and LDDV), light duty trucks (LDGT1 and LDDT1) with gross vehicle weight less than or equal to 6000 pounds, light duty trucks (LDGT2 and LDDT2) with gross vehicle weight greater than 6000 pounds but less than or equal to 8500 pounds (these are called medium duty trucks in California), heavy duty trucks (HDGT and HDDT) with gross vehicle weight greater than 8500 pounds, and motorcycles.

The definition of the federal groupings were determined by the EPA and reflect a knowledge of the change in emission standards and emission control technology. The definition of the California groupings were also derived by TSC using our own knowledge of emission standard changes and changes in control

TABLE 2.1 DEFINITION OF MODEL YEAR GROUP FOR LIGHT DUTY GASOLINE VEHICLES FOR HC

California	Federal	Major Emission Control Devices	Emission Standard [a]
Pre 66	Pre 68	None	None
66-67	68-69	Air Pump	275 ppm
68-69	68-69	Air Pump	50-100 CID 410 ppm 101-140 CID 350 ppm Over 140 CID 275 ppm
70-71	70-71	Air Pump (California 71 has EGR)	2.2 gm/mile
72-73	72-74	Air Pump, EGR	3.2 gm/mile (3.4 gm/mile) [b]
74	72-74	Air Pump, EGR, with stringent NO_x standard for California	3.2 gm/mile (3.4 gm/mile)
75-76	75-79	Air Pump, EGR, oxidizing catalyst	0.9 gm/mile (1.5 gm/mile)
77-79	80	Air Pump, EGR, oxidizing catalyst	0.41 gm/mile (1.5 gm/mile)
80+	81	3-Way Catalyst	0.39 gm/mile (0.41 gm/mile)

a = test procedure prior to 66 is 7-mode, between 72-74 is CVS-72 and for 75+ is CVS-75.

b = standard in parentheses indicates federal standard

TABLE 2.2 DEFINITION OF MODEL YEAR GROUP FOR LIGHT DUTY GASOLINE VEHICLES FOR CO

California	Federal	Major Emission Control Devices	Emission Standard[a]
Pre 66	Pre 68	None	None
66-67	68-69	Air Pump	1.5%
68-69	68-69	Air Pump	50-100 CID 2.3% 101-140 CID 2.0% over 140 CID 1.5%
70-71	70-71	Air Pump (Calif. 71 has EGR)	39 gm/mile
72-74	72-74	Air Pump, EGR	39 gm/mile
75-76	75-79	Air Pump, EGR, oxidizing catalyst	9.0 gm/mile (15.0 gm/mile)[b]
77-79	80	Air Pump, EGR, oxidizing catalyst	9.0 gm/mile (7.0 gm/mile)
80	81+	3-Way Catalyst	9.0 gm/mile (7.0 gm/mile)

a = test procedure prior to 66 is 7-mode, between 72-74 is CVS-72 and for 75+ is CVS-75.

b = standard in parentheses indicates federal standard

TABLE 2.3 DEFINITION OF MODEL YEAR GROUP FOR LIGHT DUTY GASOLINE VEHICLES FOR NO_x

California	Federal	Major Emission Control Devices	Emission Standard[a]
Pre 66	Pre 68	None	None
66-70	68-72	Air Pump	None
71	73-74	Air Pump, EGR	4.0 gm/mile (3.0 gm/mile)
72-73	73-74	Air Pump, EGR	3.0 gm/mile
74	73-74	Air Pump, EGR with stringent NO_x Standard for California	2.0 gm/mile (3.0 gm/mile)[b]
---	75-76	Air Pump, EGR, oxidizing catalyst	3.1 gm/mile
75-76	77-79	Air Pump, EGR, oxidizing catalyst	2.0 gm/mile
77-79	80	Air Pump, EGR, oxidizing catalyst	1.5 gm/mile (2.0 gm/mile)
80+	81+	3-Way Catalyst	1.0 gm/mile

a = test procedure prior to 66 is 7-mode, between 72-74 is CVS-72 and for 75+ is CVS-75.

b = standard in parentheses indicates federal standard

TABLE 2.4 DEFINITION OF MODEL YEAR GROUP FOR LIGHT DUTY GASOLINE-POWERED TRUCKS FOR HC (GVW $\leq$ 6000 lbs)

California	Federal	Major Emission Control Devices	Emission Standard[a]
pre 66	pre 68	None	None
66-67	68-69	Air Pump	275 ppm
68-69	68-69	Air Pump	50-100 CID 410 ppm 101-140 CID 350 ppm over 140 CID 275 ppm
70-71	70-71	Air Pump (California 71 has ERG)	2.2 gm/mile
72-74	72-74	Air Pump, EGR	3.2 gm/mile (3.4 gm/mile)[b]
75	75-78	Air Pump, EGR, Oxidizing Catalyst	2.0 gm/mile
76-78	75-78	Air Pump, EGR, Oxidizing Catalyst	0.9 gm/mile (2.0 gm/mile)
79-80	79-80	Air Pump, EGR, Oxidizing Catalyst	0.41-0.39 gm/mile (2.0 gm/mile)
-----	81	Air Pump, EGR, Oxidizing Catalyst	1.7 gm/mile
-----	82	Air Pump, EGR, Oxidizing Catalyst	1.7 gm/mile
81+	85+	3-way Catalyst	0.39 (0.8 gm/mile)

a = test procedure given to 66 is 7-mode, between 72-74 is CVS-72 and it is CVS-75 for 75 and later.

b = standards in parentheses indicates Federal standards.

TABLE 2.5 DEFINITION OF MODEL YEAR GROUP FOR LIGHT DUTY GASOLINE-POWERED TRUCK FOR CO (GVW $\leq$ 6000 lbs)

California	Federal	Major Emission Control Devices	Emission Standard[a]
pre 66	pre 68	None	None
66-67	68-69	Air Pump	1.5%
68-69	68-69	Air Pump	50-100 CID 2.3% 101-140 CID 2.0% over 140 CID 1.5%
70-71	70-71	Air Pump (California 71 has EGR)	2.3 gm/mile
72-74	72-74	Air Pump, EGR	39 gm/mile
75	75-78	Air Pump, EGR, Oxidizing Catalyst	20 gm/mile
76-78	75-78	Air Pump, EGR, Oxidizing Catalyst	17 gm/mile (20 gm/mile)[b]
79-80	79-80	Air Pump, EGR, Oxidizing Catalyst	9 gm/mile (18 gm/mile)
-----	81	Air Pump, EGR, Oxidizing Catalyst	18 gm/mile
-----	82	Air Pump, EGR, Oxidizing Catalyst	18 gm/mile
81+	85+	3-way Catalyst	9 gm/mile (9.4 gm/mile)

a = test procedure is CVS-72.

b = standards in parentheses incidates Federal standards.

TABLE 2.6 DEFINITION OF MODEL YEAR GROUP FOR LIGHT DUTY GASOLINE-POWERED TRUCK FOR NO_x (GVW $\leq$ 6000 lbs)

California	Federal	Major Emission Control Devices	Emission Standard [a]
pre 66	pre 68	None	None
66-70	68-72	Air Pump	None
71	73-74	Air Pump, EGR	4.0 gm/mile (3.0 gm/mile)[b]
72-73	73-74	Air Pump, EGR	3.0 gm/mile
74	73-74	Air Pump, EGR	2.0 gm/mile (3.0 gm/mile)
75	75-78	Air Pump, EGR Oxidizing Catalyst	2.0 gm (mile) (3.1 gm/mile)
76-78	75-78	Air Pump, EGR, Oxidizing Catalyst	2.0 gm/mile (3.1 gm/mile)
79-80	79-82	Air Pump, EGR, Oxidizing Catalyst	1.5 gm/mile (2.3 gm/mile)
-----	83-84	Air Pump, EGR, Oxidizing Catalyst	2.3 gm/mile
81+	85+	3-way Catalyst	1.0 gm/mile (1.4 gm/mile)

a =

b = standard in parentheses indicates Federal standard.

TABLE 2.7 DEFINITION OF MODEL YEAR GROUP FOR MEDIUM DUTY GASOLINE-POWERED TRUCK FOR HC

California	Federal[a]	Major Emission Control Devices	Emission Standard
Pre 69	Pre 70	None	None
69-71	70-73	Air Pump, Engine Modification	275 ppm
72	70-73	Air Pump, Engine Modification	180 ppm (275 ppm)[b]
73-74	74-78	EGR	None
75-76	74-78	EGR	None
77	74-78	EGR	1.0 gm/BHP-hr. (None)
78-80	79-80	EGR, Oxidizing Catalyst	0.9 gm/mile (1.7 gm/mile)
-----	81	EGR, Oxidizing Catalyst	(1.7 gm/mile)
-----	82	EGR, Oxidizing Catalyst	(1.7 gm/mile)
81+	85+	3-way Catalyst	0.39 gm/mile (0.8 gm/mile)

a = As for federal vehicles, it is under the category of LDGT2

b = Standard in parentheses indicates federal standard

TABLE 2.8 DEFINITION OF MODEL YEAR GROUP FOR MEDIUM DUTY GASOLINE-POWERED TRUCK FOR CO

California	Federal[a]	Major Emission Control Devices	Emission Standard
Pre 69	Pre 70	None	None
69-71	70-73	Air Pump, Engine Modification	1.5%
72	70-73	Air Pump, Engine Modification	1.0% (1.5%)[b]
73-74	74-78	EGR	40 gm/BHP-hr.
75-76	74-78	EGR	30 gm/BHP-hr. (40 gm/BHP-hr)
77	74-78	EGR	25 gm/BHP-hr. (40 gm/BHP-hr.)
78-80	79-80	EGR, Oxidizing Catalyst	17 gm/mile (18 gm/mile)
-----	81	EGR, Oxidizing Catalyst	(18 gm/mile)
-----	82	EGR, Oxidizing Catalyst	(18 gm/mile)
-----	83-84	EGR, Oxidizing Catalyst	(18 gm/mile)
81-82	85+	3-way Catalyst	9 gm/mile (10 gm/mile)
83+	85+	3-way Catalyst	7 gm/mile (10 gm/mile)

a = As for federal vehicles, it is under the category of LDGT2

b = Standard in parentheses indicates federal standard

TABLE 2.9 DEFINITION OF MODEL YEAR GROUP FOR MEDIUM DUTY GASOLINE-POWERED TRUCK FOR NO_x

California	Federal[a]	Major Emission Control Devices	Emission Standard
pre 69	pre 70	None	None
69-71	70-73	Air Pump, Engine Modification	None
72	70-73	Air Pump, Engine Modification	None
73-74	74-78	EGR	16 gm/BHP-hr.
75-76	74-78	EGR	10 gm/BHP-hr. (16 gm/BHP-hr.)
77	74-78	EGR	5 gm/BHP-hr. (16 gm/BHP-hr.)
78-80	79-82	EGR, Oxidizing Catalyst	2.3 gm/mile
-----	83-84	EGR, Oxidizing Catalyst	(2.3 gm/mile)
81-82	85+	3-way Catalyst	1.5 gm/mile (0.9 gm/mile)
83+	85+	3-way Catalyst	1.0 gm/mile (0.9 gm/mile)

a = As for federal vehicle, it is under the category of LDGT2

b = Standard in parentheses indicates federal standard

TABLE 2.10 DEFINITION OF MODEL YEAR GROUP FOR HEAVY DUTY GASOLINE-POWERED VEHICLES

California	Federal	Major Emission Control Devices	Emission Standard
1) Hydrocarbons			
pre 69	pre 70	None	None
69-71	70-73	Air Pump	275 ppm
72	70-73	Air Pump	180 ppm (275 ppm)[a]
73-74	74-78	Air Pump, EGR	None
75-76	74-78	Air Pump, EGR	"
77-79	79-83	Air Pump, EGR	1.5 gm/BHP-hr
80-82	79-83		1.0 gm/BHP-hr (1.5 gm/BHP-hr)
83+	79-83		0.5 gm/BHP-hr (1.5 gm/BHP-hr)
2) Carbon Monoxide			
Pre 69	pre 70	None	None
69-71	70-73	Air Pump	1.5%
72	70-73	Air Pump	1.0% (1.5%)[a]
73-74	74-78	Air Pump, EGR	40 gm/BHP-hr
75-76	74-78	" " "	30 gm/BHP-hr(40 gm/BHP-hr)
77-79	79-83	Air Pump, EGR	25 gm/BHP-hr
80-82	79-83		25 gm/BHP-hr
83+	79-83		25 gm/BHP-hr
3) Oxides of Nitrogen			NO_x / $HC + NO_x$
pre 69	pre 70	None	None / None
69-71	70-73	Air Pump	None / None
72	70-73	" "	None / None
73-74	74-78	Air Pump, EGR	None / 16
75-76	74-78	" " , "	None / 10 (16)
77-79	79-83	" " , "	7.5 (None) / 5 (5-10)
80-82	79-83		None / 5-6 (5-10)
83+	79-83		None / 4.5 (5-10)

a = Standards in parentheses indicates federal standard

TABLE 2.11 DEFINITION OF MODEL YEAR GROUP FOR LIGHT DUTY DIESEL-POWERED VEHICLES

	California	Federal	Emission Standard
Hydrocarbons			
	pre 75	pre 75	None
	75-76	75-76	1.5 gm/mile
	77	77	1.5 gm/mile
	78	78	1.5 gm/mile
	79	79	1.5 gm/mile
	80	80+	0.39 gm/mile (0.41 gm/mile)[a]
	81	80+	0.41 gm/mile
	82+	80+	0.39 gm/mile (0.41 gm/mile)
Carbon Monoxide			
	pre 75	pre 75	None
	75-76	75-76	15 gm/mile
	77	77	15 gm/mile
	78	78	15 gm/mile
	79	79	15 gm/mile
	80	80+	9.0 gm/mile (7.0 gm/mile)
	81	80+	3.4 gm/mile (7.0 gm/mile)
	82+	80+	7.0 gm/mile
Oxides of Nitrogen			
	pre 75	pre 75	None
	75-76	75-76	3.1 gm/mile
	77	77	2.0 gm/mile
	78	78	2.0 gm/mile
	79	79 or 80	2.0 gm/mile
	80	81-82	1.5 gm/mile (1.0 gm/mile)
	81	81-82	1.5 gm/mile (1.0 gm/mile)
	82+	83+	1.0 gm/mile

a = Standard in parentheses indicates federal standard

TABLE 2.12 DEFINITION OF MODEL YEAR GROUP[a] FOR LIGHT DUTY DIESEL-POWERED TRUCK 1 (GVW ≤ 6000 lbs)

California	Federal	Emissions Standard (in gm/mile) HC	CO	NO_x
Inertia Weight 0-3999 lbs				
pre 78	pre 79	None (None-2.0)[a]	None (None-20)[b]	None (None-3.1)[a]
-----	79	(1.7)	(18.0)	(2.3)
-----	80-82	(1.7)	(18.0)	(2.3)
78	83-84	0.9 (0.8)	17.0 (10.0)	2.0 (2.3)
79+	85+	0.41 (0.8)	9.0 (10.0)	1.5 (0.9)
Inertia Weight 4000-6000 lbs				
pre 78	pre 79	None (None,2.0)	None (None, 20.0)	None (None, 3.1)
-----	79	(1.7)	(18.0)	(2.3)
-----	80-82	(1.7)	(18.0)	(2.3)
78-82	83-84	0.5 (0.8)	9.0 (10.0)	2.0 (2.3)
83+	85+	0.5 (0.8)	9.0 (10.0)	1.5 (0.9)

a = the model year group are the same for all three pollutants

b = standard in parentheses indicates federal standard

TABLE 2.13 DEFINITION OF MODEL YEAR GROUP[a] FOR LIGHT DUTY DIESEL-POWERED TRUCK 2 (6001 ≤ GVW ≤ 8500)

California	Fedearl	Emission Standard (gm/mile) HC	CO	NO_x
Inertia Weight 0-3999 lbs				
pre 78	pre 78	None	None	None
78-80	83-84	0.9 (0.8)[b]	17.0 (10.0)[b]	2.3
81+	85+	0.39 (0.8)	9.0 (10.0)	1.0 (0.9)
Inertia Weight 4000-6000 lbs				
pre 78	pre 78	None	None	None
78-80	83-84	0.9 (0.8)	17.0 (10.0)	2.3
81-82	83-84	0.39 (0.8)	9.0 (10.0)	1.5 (2.3)
83+	85+	0.41 (0.8)	7.0 (10.0)	1.0 (0.9)
Inertia Weight 6001-8500 lbs				
pre 78	pre 78	None	None	None
78-80	83-84	0.9 (0.8)	17.0 (10.0)	2.3
81-82	83-84	0.5 (0.8)	9.0 (10.0)	2.0 (2.3)
83+	85+	0.5 (0.8)	9.0 (10.0)	1.5 (0.9)

a = model year group is the same for all three pollutants

b = standard in parentheses indicates federal standard

TABLE 2.14 DEFINITION OF MODEL YEAR GROUP FOR HEAVY DUTY DIESEL-POWERED VEHICLES

California	Federal	Emission Standard	
		California	Federal
Hydrocarbons			
pre 77	pre 85	None	pre 78 = None 79-83 = 1.5 gm/BHP-hr 84 = 1.3 gm/BHP-hr
77-79	pre 85	1.0 gm/BHP-hr	
80-82	pre 85	1.0 gm/BHP-hr	
83+	85+	0.5 gm/BHP-hr	1.3 gm/BHP-hr
Carbon Monoxide			
pre 77	pre 85	pre 73 = None 73-74 = 40 gm/BHP-hr 75-76 = 30 gm/BHP-hr	pre 73 = None 73 = 1.5% 74-78 = 40 gm/BHP-hr 79-83 = 25 gm/BHP-hr 84 = 15.5 gm/BHP-hr
77-82	pre 85	25 gm/BHP-hr	
83+	85+	25 gm/BHP-hr	15.5 gm/BHP-hr
Oxides of Nitrogen			
pre 77	pre 85	None	pre 84 = None 84 = 10.7 gm/BHP-hr
77-79	pre 85	7.5 gm/BHP-hr	
80-82	pre 85	None	
83+	85+	None	1.7 gm/BHP-hr

TABLE 2.15 DEFINITION OF MODEL YEAR GROUP FOR MOTORCYCLE

California	Federal	Emission Standard
Hydrocarbon		
pre 78	pre 78	None
78-79	78-79	50-169 c.c. 5.0 gm/km
		170-749 c.c. 5.0 + 0.0155 (D-170) gm/km
		Over 749 c.c. 14 gm/km
80-81	80+	5.0 gm/km
82+	80+	1.0 gm/km (5.0 gm/km)[a]
Carbon Monoxide		
pre 78	pre 78	None
78-79	78-79	17 gm/km
80-81	80+	12 gm/km
82+	80+	12 gm/km
Oxides of Nitrogen		
pre 78	pre 78	None
78-79	78-79	None
80-81	80+	None
82+	80+	None

[a]Standard in parentheses indicates federal standards.

technology. This knowledge was supplemented by a literature review, conversations with EPA personnel (especially the task officer) and with engineers in the automotive industry. The interaction between NO_x and HC controls was also taken into account in deriving the model year groups for California vehicles.

2.2 MATCHING MODEL YEAR GROUPS

The main purpose of this subtask was to find a federal model year group that would correspond to each California model year group. Tables 2.1 through 2.15 indicate which federal group corresponds to each California model year group for each emission and vehicle class.

The reasons, as far as standards and control technology, are given in these tables. It should be noted that there is not a strict one to one correspondence between federal and California model year groups because of major differences in standards or control technology.

Different California model year groups can go with the same federal model year group. This was done because of the requirement that each California model year group match a federal model year group. The two California groups should not be lumped together. The reasons for separating any two groups are listed in the table as they occur.

3. HOMOGENEITY OF THE SIX ARB DATA SETS

The Air Resources Board in El Monte, California has performed a series of Surveillance Test Programs for several types of California vehicles. Vehicle characteristics of data has been collected for each of these vehicles and constant volume sampling (CVS-75) emissions test used in certification. Under this program there were thirteen reports published by the ARB. TSC examined data contained in the following six reports:

1. 1975-1976 Model Year Surveillance Test Program Report
2. Final Report of the High Mileage Catalyst Vehicle Surveillance Test Program, 1st Series, CVS (CARB Report No. 4).
3. Medium Duty Vehicle Surveillance Test Program Series II, CVS (CARB Report No. 7).
4. Twenty Additional Datsun Motor Vehicle Surveillance Test Program Report (CARB Report No. 8).
5. Limited Surveillance Program to Determine Whether Early Catalyst Failures are Occurring in 1975 Model Year Vehicles (CARB Report No. 11).
6. Final Report of the Light-Duty Vehicle Surveillance Test Program, 2nd Series, CVS (LDVSP-II) (CARB Report No. 10).

The objective of this chapter is to examine the six ARB reports for information relating to vehicles and to CVS-75 emissions testing and to determine whether the data from the different reports can be combined.

3.1 VEHICLE SELECTION AND CVS-75 EMISSION TEST

According to the ARB reports, each data set was selected for a different purpose. For report No. 1, the vehicles were selected randomly by a private-vehicle procurement contractor, in order to be representative

of 1975 and 1976 model year vehicles. Report No. 4 examined high mileage catalyst vehicles. The samples are from 1975 and 1976 model year vehicles with mileage greater than 50,000 miles. The data set for Report No. 7 was representative of the California medium duty truck population which was selected by Systems Controls, Inc. Report No. 8 had 20 additional vehicles which were randomly selected to be representative of 1973 to 1977 model-year Datsun vehicles. In Report No. 11, most of the vehicles were obtained from car dealers or rental agencies. They were not selected to represent sales. As for Report No. 12, the samples were designed to represent the California State population.

Although the sampling purposes were different for each report, the testing procedure of CVS-75 was exactly the same. Each vehicle had a CVS-75 test "as received." It required a twelve hour cold soak prior to testing. Then, bag samples were taken during the cold start, cold transient and hot start cycles. The emission concentrations of hydrocarbons (HC), carbon monoxide (CO) and nitrogen oxides (NO_x) as determined from each of these bag samples were used to calculate the average grams per mile over the total test distance.

3.2 COMBINED DATA SET

Since the test procedure for each report was the same, all the data can be included in the data bank. However, the combined data set cannot be assumed to be representative of the California State fleet population, since the sampling plan for each report was different. The combined data

set is valid for the study of each model year group because it contains both high mileage or low mileage vehicles in each group.

There are twenty-one Datsun vehicles replicated in Report Nos. 1 and 4. Therefore, when combining data sets, the replicates were deleted from Report No. 4's data set.

In the combined data set, there are 781 light duty vehicles, 96 light duty trucks, and 75 medium duty trucks. The total number of vehicles is 952.

4. DATA VERIFICATION FOR CARB DATA SET

Prior to performing analyses on the data, it was necessary to perform data verification on the data set received. This was done by analyzing the values in the data set and then comparing them to those given in the ARB reports. When a value was found to be missing or incorrect, it was changed to reflect the information given in the reports. Table 4.1 summarizes the changes that were made in the data set. The following sections describe the changes that were made in the data set in detail and state the reason for changes. Each section contains one ARB report.

4.1 CARB REPORT NUMBER ONE

In this report, eleven of the vehicles, while being American makes, were actually manufactured by Japanese companies. Three Chrysler cars had been manufactured by Mitsubishi, four GM cars had been manufactured by Isuzu, and four Ford cars had been manufactured by Mazda. Therefore, the values of the manufacturer variables were changed to reflect this. A value had already been assigned to them: 36 for Mitsubishi, and 37 for Isuzu. The four Ford's were changed from a 6 to an 11. The only other change was that one car had "EG" as one of its emission control devices. This was changed to "EGR" and was most likely a keypunch error.

4.2 CARB REPORT NUMBER FOUR

All of the vehicles tested for this report were light-duty vehicles; however, all the values for the vehicle type variable had been set to zero. These values were changed to 1 for all 66 cases. The values of the pass/fail

TABLE 4.1 SUMMARY OF CHANGES MADE DURING DATA VERIFICATION

CARB Report Number	Variable	Change From	Change To	Number of Vehicles	Vehicle Numbers
1	MFG	9	36	3	109,150,172
	MFG	1	37	4	11,27,180,182
	MFG	6	11	4	92,107,110,133
	EM Dev	EG-...	EGR-...	1	84
4	Veh Type	0	1	66	1-64 (All)
	P or F	10000	1	8	3,14,15(-1),18,24,39,50,64,
	P or F	10000	2	6	11,15(-2),17,40,43,60
	P or F	20000	3	52	1,2,4-10,12,13,16,19-23, 25(-1), 25(-2),26-38,41,42,44-49, 51-59,61-63
	MYR	75	76	2	7,57
	MYR	76	75	5	8,9,32,56,61
	EM Dev	(Blank)	AIR-EGR-OC	1	16
	EM Dev	...-CO	...-OC	2	26,64
7	Veh Type	0	3	75	All
	MFG	0	6	38	All Ford trucks
	MFG	0	21	4	77,63,50,12
	MFG	0	1	15	47,58,15,17,35,62,10,14,29, 57,60,4,56,36,22
	MFG	0	9	13	9,37,7,13,42,64,65,27,61,54, 80,44,52
	MFG	0	38	1	70
	Make	99	38	1	70
	MFG	0	98	4	31,81,53,48
	Make	31	98	4	31,81,53,48
8	CA/Fed	0	1	20	1-20 (All)
11	Veh Type	0	1	182	All
	CID	2300(cc)	140(cu.in.)	9	20001,20004,20006,20023, 20041,20073,21077,21079,21081
	CID	2800(cc)	171(cu.in.)	1	21078
	CID	1400(cc)	85(cu.in.)	2	23001,23008
	Em Dev	(Blank)	AI-EGR-OC	130	All AMC, Chrysler and GM (except Buick); 6 Imports
	Em Dev	(Blank)	EGR-OC	43	All Ford (except for the 9 with 2300 cc CID) and GM (Buick; 2 Imports
12	MFG	6	14	25	
	MFG	6	33	6	4170,4181,4334,4344,4376,4385
	MFG	6	39	2	4027,4093
	MFG	9	36	6	4323,4329,4342,4373,4397,4398
	MFG	1	37	10	4056,4175,4215,4260,4261,4262, 4339,4386,4391,4392
	MFG	1	17	1	4332
	Make	0	1	1	4332
	Em Dev	CVCC	EM	1	1020
	EM Dev	*	EM	2	4018,4039
	Em Dev	REGR	EGR	1	4296
	Em Dev	...-EG	...-EGR	1	4260
	Em Dev	...-E	...-EFI	1	4330
	Em Dev	...-EFE-	...-EFE-OC	1	4378
	Em Dev	...-E	...-EFE	1	4382
	Em Dev	...-EGR-	...-EGR-OC	1	4383
	Veh Type	2	1	1	4237
	CA/Fed	8	1	2	4213,4214
	Odom	5841	35841	1	4213
	Iner Wt	5003	5500	1	4213
	Cyl	1	8	1	4213
	Trans	5	1	1	4213

variables for all the cases had been set to 10,000 for pass or pass marginally, and 20,000 for fail. Eight of the values were changed to 1 for pass, six were changed to 2 for pass marginally, and 52 were changed to 3 for fail. The changes to pass or pass marginally were based upon the data listings in the report. Two were changed from 75 to 76, and five were changed from 76 to 75. One vehicle was missing the emission control device listed for it in the report, so it was added. Finally, two vehicles had CO listed as one of their emission control devices and they were changed to OC. The disagreement between the data set and the report for the model year and emission control device variables were most likely due to keypunch errors.

4.3 CARB REPORT NUMBER SEVEN

All of the vehicles tested for this report were medium-duty trucks; however, all the values for the vehicle type variable had been set to zero. These values were changed to 3 for all 75 cases. Secondly, while values were present for the make variable, the values for the manufacturer variable had all been set to zero. These were changed according to the tables in the report. Thirty-eight were Ford trucks, four were GMC, 15 were GM, and 13 were Chrysler. One vehicle was a Jeep which had no value assigned to it. Therefore, we assigned Jeep the value 38 and changed both the manufacturer and make (which had been 99 for other) to this value. Four of the vehicles were International Harverster.. The value 31 is a Renault if the vehicle is a car or International Harvester if the vehicle is a truck. To avoid confusion, we decided to leave Renault with the value 31 and reassign International Harvester to the value of 98. Therefore, for the four International Harvester

vehicles, we changed the values of the manufacturer variable from 0 to 98, and the make variable from 31 to 98.

4.4 CARB REPORT NUMBER EIGHT

For this report, all 20 vehicles had a value of zero for the California/Federal variable. These values were changed to 1 to indicate California emission controls.

4.5 CARB REPORT NUMBER ELEVEN

All of the vehicles tested for this report were light-duty vehicles; however, all the values for the vehicle type variable had been set to zero. These values were changed to 1 for all 182 cases. Twelve of the vehicles had values for their cubic inch displacement in cubic centimeters so these values were converted into cubic inches. Nine Fords were changed from 2300 cc. to 140 cu. in., one Ford was changed from 2800 cc. to 171 cu. in., and two Datsuns were changed from 1800 cc. to 85 cu. in. Finally, none of the vehicles had their emission control devices listed. Therefore, we searched through the other reports to see which devices similar vehicles had, and then assigned those same devices to the vehicles in Report 11. Vehicles for which no information was found were left blank. This happened for the nine Fords which had 2300 cc. for their cu. in. displacement. The emission control device was changed to AI-EGR-OC for 130 cases, including all the AMC, Chrysler, and GM (except for Buick) vehicles and six imported cars. The emission control device was changed to EGR-OC for 43 cases, including all the Fords (except for the nine vehicles left blank) and Buick-GM vehicles and two imported cars.

Another problem which was noticed, but for which no change was made, concerned the use of the same vehicle number for more than one vehicle. In the report, each vehicle was identified by a test number consisting of a series of letters and numbers. This was converted to the vehicle number in the data set by taking the number portion of the test number and adding it to 100 times the page number on which the data appeared in the report. Thus, test number CAL 74 on page 21 became vehicle number 21074. For most of the pages, the letter portions of the test number would remain the same and the number portions would change. But for the imported cars on page 23, some of the test numbers and the same number portion and differed only in the letter portion. Thus the conversion resulted in assigning the same number to more than one vehicle. The vehicles with the same numbers were of different manufacturers and makes, so they can be distinguished from one another by those variables in the data set, but one cannot refer to them by vehicle number alone.

4.6 CARB REPORT NUMBER TWELVE

A number of the vehicles in this report, while being American makes, were actually manufactured by companies in other countries. However, the manufacturer variables for these cars had the values of the American companies. Therefore, the values were changed according to the information given in the report. Twenty-five of the Fords were manufactured by Nissan so the values were changed to 14 for Datsun. Six of the Fords were Couriers so their values were changed to 33 which is the value assigned to Courier. One Ford was a Capri and another was a Cartina. Both are manufactured in Europe.

We assigned the value 39 to them to represent European-made Ford passenger vehicles. Six Chryslers were manufactured by Mitsubishi so their values were changed to 36, and ten GM vehicles were manufactured by Isuzu so their values were changed to 37. These values, 36 and 37, were assigned to these manufacturers in Section 4.1 for vehicles in CARB Report Number 1. One vehicle was listed as GM-Opel, so its manufacturer variable was changed from 1 to 17 for Opel, and its make variable was changed from 0 to 1 for Buick. All the vehicles in this report had a value of zero for the make variable; however, the Opel was the only vehicle for which that value was changed.

Four of the vehicles had what appeared to be keypunch errors in their lists of emission control devices. One was changed from CVCC to EM, two were changed from "*" to EM, and one was changed from REGR to EGR. Five other vehicles had errors in their lists of emisssion control devices that could have been due to a format error in the program generating the tape. For all five vehicles, the list of devices had been chopped off after the first 11 characters so the missing letters were added. The changes were from EM-OC-FI-EG to EM-OC-FI-EGR, from AI-EGR-OC-E to AI-EGR-OC-EFI, from AI-EGR-EFE to AI-EGR-EFE-OC, from OC-EGR-AI-E to OC-EGR-AI-EFE, and from EM-EFI-EGR to EM-EFI-EGR-OC.

The rest of the errors that were found appear to be keypunch errors. One vehicle was incorrectly listed as a light-duty truck so the value for the vehicle type was changed from 2 to 1. Two vehicles had values of 8 for the California/Fedearl emission controls variable which were changed to 1. One

of these two vehicles also had errors in the odometer, inertial weight, cylinders, and transmission variables. The changes were from 5841 to 35841 for the odometer, from 5003 to 5500 for the inertial weight, from 1 to 8 for the cylinders, and from 5 to 1 for the transmission.

5. ANALYSIS

5.1 DATA BASE

In the ARB data set, there are 427 cases coded as California vehicles, 22 as federal vehicles and 503 have no code. For the purpose of this task, only California vehicles will be considered in the analyses. Therefore, 22 federal vehicles were deleted from the data base. As for the rest 503 uncoded vehicles, we know that there is a 95% chance they are California vehicles.* In order to get a good sample size for each model year group, they are included in the data base. For the non-federal vehicles, 763 are light duty gasoline-powered vehicles (LDGV), 92 are light duty gasoline-powered trucks ($LDGT_1$) and 75 are medium duty gasoline-powered truckes ($LDGT_2$). The breakdown of emission control devices and model year of the vehicle for each vehicle type are shown in Table 5.1 and Table 5.2. In Table 5.1, we note that there are three cars with emission control devices coded as "carter" or "carter RST." Since the meanings of these codes are unclear, we dropped those cars from the data base. The emission control devices were not coded for the medium duty trucks, which were in ARB report #7. The breakdown model year is shown in Table 5.3.

5.2 DESCRIPTIVE STATISTICS OF THREE EMISSIONS UNDER EACH MODEL YEAR GROUP

For each vehicle type (LDGV, $LDGT_1$ and $LDGT_2$), the vehicles are grouped based on the definitions discussed in Chapter 2. Under each model

---

*Per the conversation with the staff in ARB, El Monte

TABLE 5.1 BREAKDOWN OF MODEL YEAR AND EMISSION CONTROL DEVICE FOR LIGHT DUTY VEHICLES

Emission Control Device	model year										
	68	69	70	71	72	73	74	75	76	77	total
None (or no code)	17	13	22	16	18	10		8	1		114
FE			2	1		1					4
EM	1	1	1	2	2	2		5	7		21
EGR	2	2	1	11	10						26
EGR-FE						1	1	1			3
EGR-EM-EFE								1			1
EGR-TR										1	1
EGR-OC								56	17		73
EGR-OC-EFE								6	8		14
EGR-OC-FE								4	1	3	8
EGR-OC-EM-EFE									1	1	2
EGR-OC-EM-FE								1		1	2
AI	2	2	1	4	7	1	2				19
AI-TR				1			1	1			3
AI-OC								3		6	9
AI-OC-FE									1		1
AI-OC-EM								4	3		7
AI-EGR									1	1	2
AI-EGR-EFF								1	1		2
AI-EGR-TR								4	5	2	11
AI-EGR-TR-EM									1		1
AI-EGR-OC								220	105	52	379
AI-EGR-OC-EFE								4	5	2	11
AI-EGR-OC-FE								1	3		4
AI-EGR-OC-EM								8	5		13
AI-EGR-OC-EM									1		
CARTER		2									
CARTER RST		2									
NOX or RNOX	3	3									
Total	25	24	26	24	30	35	34	328	174	63	763

TABLE 5.2 BREAKDOWN OF MODEL YEAR AND EMISSION CONTROL DEVICE FOR LIGHT DUTY TRUCKS

Emission Control Device	model year 72	73	74	75	76	77	total
None (or no code)		1					1
EGR			1	1			2
EGR-EM-EFE				2			2
EGR-OC				2	8	4	14
EGR-OC-EFE				1		1	2
EGR-OC-EM-EFE				1			1
AI	1			4			5
AI-OC					1		1
AI-EGR				13			13
AI-EGR-TR					2		2
AI-EGR-OC				6	22	18	46
AI-EGR-OC-EFE				1			1
AI-EGR-OC-EM					2		2
Total	1	1	1	31	35	23	92

TABLE 5.3 BREAKDOWN OF MODEL YEAR FOR MEDIUM DUTY TRUCKS

MODEL YEAR	# OF CASES
67	3
68	1
69	2
70	3
71	2
72	3
73	3
74	6
75	14
76	16
77	15
78	7
total	75

year group, the descriptive statistics for both emissions level and mileage are calculated. The results for light duty vehicles are shown in Tables 5.4 through 5.9. We note that there are two declines among the model year groups. The smaller one is between 69 and 70. The bigger one is between 74 and 75. This phenomena appears for all the three emissions.

For light duty trucks the descriptive statistics for the three emissions are shown in Tables 5.10 through 5.12. There is also a decreasing trend for model year 72-74, however, the sample size is too small to make any strong conclusions. The situation is similar for medium duty trucks. The results are in Tables 5.13 through 5.16.

5.3 REGRESSION ANALYSIS BETWEEN EMISSIONS AND ODOMETER READINGS

The usual method of determining the deterioration factor is to find the linear relationship between emissions and odometer readings. The linear equation is written in the form $E = b + dM$, where E is the emissions, b is the new car emissions (intercept), d is the deterioration factor and M is the mileage in thousands of miles. The coefficients are estimated using regressions using the following model: $E = b + dM + e$, where e is the residual error.

In Tables 5.17 to 5.23 are given the regression results, using a linear model for hydrocarbon, carbon monoxide, and nitrogen dioxide emissions for the three types of gasoline powered vehicles LDGV, LDGT4, and LDGT2.

In general, the percent variation explained by the model ($100.r^2$) is small (less than 20%). This indicates that using the linear model to describe emissions using mileage with this data is not appropriate in the statistical sense.

TABLE 5.4 DESCRIPTIVE STATISTICS FOR CALFIORNIA LIGHT DUTY GASOLINE VEHICLES' HYDROCARBON EMISSIONS IN EACH HYDROCARBON MODEL YEAR GROUP (in gm/mile)

Model Year Group	Sample Size	Means	Standard Deviation	Range	Minimum	Maximum
Pre 66	None					
66-67	None					
68-69	46	6.62	5.63	24.1	1.72	25.82
70-71	50	4.41	2.42	11.81	1.08	12.89
72-73	65	4.79	5.96	34.55	1.18	35.73
74	34	4.54	5.50	29.40	1.23	30.63
75-76	502	0.97	1.63	24.80	0.13	24.93
77-79	63	0.50	0.23	1.23	0.14	1.37
80^{+}	None					
Total	760	1.99	3.44	35.60	0.13	35.73

TABLE 5.5 DESCRIPTIVE STATISTICS FOR CALIFORNIA LIGHT DUTY GASOLINE VEHICLES' MILEAGE IN EACH HYDROCARBON MODEL YEAR GROUP (in miles)

Model Year Group	Sample Size	Means	Standard Deviation	Range	Minimum	Maximum
Pre 66	None					
66-67	None					
68-69	46	79,476	26,270	121,757	27,006	148,763
70-71	50	84,519	26,309	127,734	24,407	152,141
72-73	65	63,750	21,523	102,519	14,661	117,180
74	34	47,776	15,274	55,201	24,389	79,590
75-76	502	21,561	20,743	88,848	12	88,860
77-79	63	13,707	6,715	28,718	1,319	30,037
80^{+}	None					
Total	760	33,338	30,600	152,129	12	152,141

TABLE 5.6 DESCRIPTIVE STATISTICS FOR CALFIORNIA LIGHT DUTY GASOLINE VEHICLES' CARBON MONOXIDE EMISSIONS IN EACH CARBON MONOXIDE MODEL YEAR GROUP (in gm/mile)

Model Year Group	Sample Size	Means	Standard Deviation	Range	Minimum	Maximum
Pre 66	None					
66-67	None					
68-69	46	76.55	49.44	185.22	9.02	194.24
70-71	50	62.76	38.17	159.36	13.63	172.99
72-74	99	52.71	37.57	211.16	6.80	217.96
75-76	502	11.37	16.54	133.51	0.31	133.82
77-79	63	6.06	5.81	25.27	1.38	26.65
80^{+}	None					
Total	760	23.64	33.32	217.65	0.31	217.96

TABLE 5.7 DESCRIPTIVE STATISTICS FOR CALIFORNIA LIGHT DUTY GASOLINE VEHICLES' MILEAGE IN EACH CARBON MONOXIDE MODEL YEAR GROUP (in miles)

Model Year Group	Sample Size	Means	Standard Deviation	Range	Minimum	Maximum
Pre 66	None					
66-67	None					
68-69	46	79,476	26,270	121,757	27,006	148,763
70-71	50	84,519	26,309	249,491	24,407	152,141
72-74	99	58,264	20,957	102,519	14,661	117,180
75-76	502	21,561	20,743	88,848	12	88,860
77-79	63	13,707	6,715	28,718	1,319	30,037
80^{+}	None					
Total	760	33,338	30,600	152,129	12	152,141

TABLE 5.8 DESCRIPTIVE STATISTICS FOR CALIFORNIA LIGHT DUTY VEHICLES' OXIDES OF NITROGEN EMISSIONS IN EACH NO_x MODEL YEAR GROUP (in gm/miles)

Model Year	Sample Size	Mean	Standard Deviation	Range	Minimum	Maximum
Pre 66	None					
66-70	72	3.19	1.36	6.08	0.50	6.58
71	24	2.74	1.23	4.79	0.47	5.26
72-73	65	2.85	1.14	6.26	0.53	6.79
74	34	2.89	1.60	6.77	0.41	7.18
75-76	502	2.15	1.19	8.43	0.41	8.84
77-79	63	1.84	1.13	4.99	0.72	5.71
80^+	None					
Total	760	2.34	1.27	8.43	0.41	8.84

TABLE 5.9 DESCRIPTIVE STATISTICS FOR CALIFORNIA LIGHT DUTY VEHICLES' MILLAGE IN EACH NO_x MODEL YEAR GROUP (in mile)

Model Year	Sample Size	Mean	Standard Deviation	Range	Minimum	Maximum
Pre 66	None					
66-70	72	83,628	25,246	121,757	27,006	148,763
71	24	77,528	29,233	127,734	24,407	152,141
72-73	65	63,750	21,523	102,519	14,661	117,180
74	34	47,777	15,274	55,201	24,389	79,590
75-76	502	21,561	20,743	88,848	12	88,860
77-79	63	13,708	6,715	28,718	1,319	30,037
80^+	None					
Total	760	33,338	30,600	152,129	12	152,141

TABLE 5.10 DESCRIPTIVE STATISTICS FOR CALIFORNIA LIGHT DUTY TRUCKS FOR EACH HYDROCARBON MODEL YEAR GROUP

Model Year Group	Sample Size	Mean	Standard Deviation	Range	Minimum	Maximum
Hydrocarbon (in gm/mile)						
72-74	3	5.08	2.88	5.35	3.02	8.37
75	31	3.22	5.10	26.85	0.73	27.58
76-78	58	0.80	0.71	3.32	0.14	3.46
Total	92	1.76	3.28	27.44	0.14	27.58
Odometer (in miles)						
72-74	3	51,728	12,922	25,576	37,867	63,443
75	31	28,825	16,027	83,009	1,857	84,866
76-78	58	16,413	9,651	49,543	1,774	51,317
Total	92	21,747	14,544	83,092	1,774	84,866

TABLE 5.11 DESCRIPTIVE STATISTICS FOR CALIFORNIA LIGHT DUTY TRUCKS IN EACH CARBON MONOXIDE MODEL YEAR GROUP

Model Year Group	Sample Size	Mean	Standard Deviation	Range	Minimum	Maximum
Carbon Monoxide (in gm/mile)						
72-74	3	47.57	42.06	84.05	6.50	90.55
75	31	21.96	16.13	59.64	7.11	66.75
76-78	58	8.71	9.36	49.37	1.23	50.60
Total	92	14.44	16.00	89.32	1.23	90.55
Odometer (in miles)						
72-74	3	51,728	12,922	25,576	37,867	63,443
75	31	28,825	16,027	83,009	1,857	84,866
76-78	58	16,413	9,651	49,543	1,774	51,317
Total	92	21,747	14,544	83,092	1,774	84,866

TABLE 5.12 DESCRIPTIVE STATISTICS FOR CALIFORNIA LIGHT DUTY TRUCKS IN EACH NITROGEN OXIDES MODEL YEAR GROUP

Model Year Group	Sample Size	Mean	Standard Deviation	Range	Minimum	Maximum
Nitrogen Oxides (in gm/mile)						
72-73	2	1.82	0.13	0.19	1.72	1.91
74	1	5.00		0.00		5.00
75	31	2.14	1.04	3.74	0.77	4.51
76-78	58	1.72	0.44	2.65	0.93	3.58
Total	92	1.90	0.79	4.23	0.77	5.00
Odometer (in miles)						
72-73	2	50,655	18,085	25,576	37,867	63,443
74	1	53,875		0		53,875
75	31	28,825	16,027	83,009	1,857	84,866
76-78	58	16,413	9,651	49,543	1,774	51,317
Total	92	21,747	14,544	83,092	1,774	84,866

TABLE 5.13 DESCRIPTIVE STATISTICS OF HYDROCARBON FOR CALIFORNIA MEDIUM DUTY TRUCK IN EACH MODEL YEAR GROUP (in gm/mile)

Model Year Group	Sample Size	Mean	Standard Deviation	Range	Minimum	Maximum
pre 69	4	9.67	6.34	13.21	5.95	19.16
69-71	7	7.64	1.76	5.12	6.06	11.18
72	3	7.60	3.72	7.04	3.38	10.42
73-74	9	5.95	1.47	4.23	4.12	8.35
75-76	30	6.23	8.24	43.78	1.52	45.30
77	15	2.94	1.32	4.72	1.03	5.75
78-80	7	1.33	1.71	4.79	0.30	5.09
Total	75	5.45	5.87	45.0	0.30	45.30

TABLE 5.14 DESCRIPTIVE STATISTICS OF CARBON MONOXIDE FOR CALIFORNIA MEDIUM DUTY TRUCK IN EACH MODEL YEAR GROUP (in gm/mile)

Model Year Group	Sample Size	Mean	Standard Deviation	Range	Minimum	Maximum
pre 69	4	74.87	23.17	55.52	51.06	103.58
69-71	7	61.43	11.90	30.96	46.43	77.39
72	3	66.16	10.52	21.03	55.88	76.91
73-74	9	77.10	19.82	65.60	47.35	112.95
75-76	30	53.76	28.58	98.16	14.66	112.82
77	15	35.61	14.04	51.14	13.55	64.69
78-80	7	20.02	28.16	78.54	4.41	82.95
Total	75	52.12	27.82	108.54	4.41	112.95

TABLE 5.15 DESCRIPTIVE STATISTICS OF NITROGEN OXIDES FOR CALIFORNIA MEDIUM DUTY TRUCK IN EACH MODEL YEAR GROUP (in gm/mile)

Model Year Group	Sample Size	Mean	Standard Deviation	Range	Minimum	Maximum
pre 69	4	4.94	1.39	3.23	3.65	6.88
69-71	7	5.72	2.01	4.79	3.31	8.10
72	3	4.01	0.33	0.65	3.71	4.36
73-74	9	5.64	2.35	6.79	1.90	8.69
75-76	30	3.83	2.03	9.56	0.41	9.97
77	15	4.70	1.79	5.89	1.95	7.84
78-80	7	2.09	0.52	1.59	1.03	2.62
Total	75	4.30	2.07	9.56	0.41	9.97

TABLE 5.16 DESCRIPTIVE STATISTICS OF ODOMETER FOR CALIFORNIA MEDIUM DUTY TRUCK IN EACH MODEL YEAR GROUP (in miles)

Model Year Group	Sample Size	Mean	Standard Deviation	Range	Minimum	Maximum
pre 69	4	95,498	12,330	29,104	83,797	112,902
69-71	7	53,773	24,713	66,649	13,259	79,908
72	3	67,217	12,499	24,361	56,656	81,017
73-74	9	53,540	16,853	55,248	31,666	86,914
75-76	30	48,201	18,725	95,379	5,755	101,134
77	15	29,479	17,007	74,729	8,677	83,406
78-80	7	10,037	6,664	18,531	2,054	20,585
Total	75	45,338	25,077	110,848	2,054	112,902

TABLE 5.17 RESULTS OF REGRESSION ANALYSIS ON HYDROCARBON EMISSIONS AND ODOMETER FOR CALIFORNIA LIGHT-DUTY GASOLINE VEHICLES

Model Year Group	Y^2	Mean Square for Regression	Mean Square for Residual	F-Value Calculated at 95%		(DF_1, DF_2)	$\hat{Intercept}$ (gm/mi)	$\hat{Slope}$ (gm/mi per 1000 mi driven)
68-69	0.004	5.93	32.34	0.18	4.06	(1,44)	7.72	-0.014
70-71	0.039	11.12	5.76	1.93	4.04	(1,48)	2.88	0.018
72-73	0.025	57.47	35.12	1.64	3.99	(1,63)	1.98	0.044
74	0.052	52.11	29.59	1.76	4.15	(1,32)	8.47	-0.082
75-76	0.073	96.83	2.46	39.41*	3.86	(1,500)	0.51	0.021
77-79	0.131	0.44	0.05	9.16*	4.00	(1,61)	0.32	0.013

* significant at the 95% level

TABLE 5.18 RESULTS OF REGRESSION ANALYSIS ON CARBON MONOXIDE EMISSIONS AND ODOMETER FOR CALIFORNIA LIGHT-DUTY GASOLINE VEHICLES

Model Year Group	Y^2	Mean Square for Regression	Mean Square for Residual	F-Value Calculated at 95%		(DF_1, DF_2)	$\hat{}$ Intercept (gm/mi)	$\hat{}$ Slope (gm/mi per 1000 mi driven)
68-69	0.008	825.46	2480.77	0.33	4.06	(1,44)	63.59	0.16
70-71	0.022	1565.76	1454.37	1.08	4.04	(1,48)	44.60	0.21
72-74	0.011	1585.93	1409.92	1.12	3.94	(1,97)	41.53	0.19
75-76	0.044	6040.84	262.12	23.05*	3.86	(1,500)	7 76	0.16
77-79	0.059	124.38	32.26	3.86	4.00	(1,61)	3.17	0.21

* significant at the 95% level

TABLE 5.19 RESULTS OF REGRESSION ANALYSIS ON NITROGEN OXIDES EMISSIONS FOR CALIFORNIA LIGHT-DUTY GASOLINE VEHICLES

Model Year Group	Y^2	Mean Square for Regression	Mean Square for Residual	F-Value Calculated at 95%		(DF_1, DF_2)	$\hat{}$ Intercept (gm/mi)	$\hat{}$ Slope (gm/mi per 1000 mi driven)
66-70	0.003	0.42	1.86	0.22	3.98	(1,70)	3.45	0.003
71	0.026	0.90	1.55	0.58	4.30	(1,22)	2.22	0.0068
72-73	0.0004	0.04	1.32	0.03	3.99	(1,63)	2.78	0.0011
74	0.041	3.45	2.52	1.37	4.15	(1,32)	1.88	0.0212
75-76	0.019	13.29	1.38	9.63*	3.86	(1,500)	1.99	0.0079
77-79	0.054	4.29	1.22	3.51	4.00	(1,61)	2.38	0.0392

* significant at the 95% level

TABLE 5.20 RESULTS FOR REGRESSION ANALYSIS FOR CALIFORNIA LIGHT-DUTY GASOLINE-POWERED TRUCKS

Model Year Group	Sample Size	γ^2	Mean Square for Regression	Mean Square for Residual	F-Value Calculated	F-Value 95% level	(DF_1, DF_2)	Intercept (gm/mile)	Slope (gm/mile per 1,000 mile Driven)
Hydrocarbon									
72-74	3	0.47	7.88	8.72	0.90	161	(1,1)	-2.870	0.154
75	31	0.19	144.81	21.89	6.62*	4.18	(1,29)	-0.727	0.137
76-78	58	0.04	1.08	0.50	2.18	4.02	(1,56)	0.566	0.014
Carbon Monoxide									
72-74	3	0.42	1493.68	2043.99	0.73	161	(1,1)	156.965	-2.115
75	31	0.07	516.33	251.25	2.06	4.18	(1,29)	29.425	-0.259
76-78	58	-.002	8.79	89.02	0.10	4.02	(1,56)	8.042	0.041
Nitrogen Oxides									
72-73	2	NA							
74	1	NA							
75	31	0.05	1.51	1.06	1.43	4.18	(1,29)	1.739	0.014
76-78	58	0.01	0.15	0.19	0.79	4.02	(1,56)	1.634	0.004

*Significant at the 95% level

TABLE 5.21 REGRESSION ANALYSIS BETWEEN HYDROCARBON AND ODOMETER FOR CALIFORNIA MEDIUM-DUTY GASOLINE-POWERED TRUCKS

Model Year Group	Sample Size	γ^2	Mean Square for Regression	Mean Square for Residual	F-value		(DF_1, DF_2)	Intercept (gm/mile)	Slope (gm/mile per 1,000 mile Driven)
					Calculated	95% level			
pre 69	4	0.85	102.07	9.33	10.95	18.51	(1,2)	-35.509	0.473
69-71	7	0.42	7.78	2.15	3.62	6.61	(1,5)	5.161	0.046
72	3	0.78	21.55	6.15	3.50	161	(1,1)	25.247	-0.263
73-74	9	0.03	0.49	2.40	0.21	5.59	(1,7)	6.744	-0.015
75-76	30	0.006	12.72	69.83	0.18	4.20	(1,28)	7.932	-0.035
77	15	0.05	1.26	1.78	0.71	4.67	(1,13)	2.42	0.018
78-80	7	0.04	0.64	3.40	0.19	6.61	(1,5)	1.822	-0.049

TABLE 5.22 REGRESSION ANALYSIS BETWEEN CARBON MONOXIDE AND ODOMETER FOR CALIFORNIA MEDIUM-DUTY GASOLINE-POWERED TRUCKS

Model Year Group	Sample Size	r^2	Mean Square for Regression	Mean Square for Residual	F-value		(DF_1, DF_2)	Intercept (gm/mile)	Slope (gm/mile per 1,000 mile Driven)
					Calculated	95% level			
pre 69	4	0.66	1062.73	274.06	3.88	18.51	(1,2)	-70.903	1.526
69-71	7	0.13	107.25	148.58	0.72	6.61	(1,5)	52.228	0.171
72	3	0.43	94.37	127.09	0.74	161	(1,1)	103.100	-0.550
73-74	9	0.04	122.01	431.29	0.28	5.59	(1,7)	64.69	0.232
75-76	30	0.05	1103.85	806.30	1.37	4.20	(1,28)	69.43	-0.329
77	15	0.05	144.18	201.33	0.72	4.67	(1,13)	41.174	-0.189
78-80	7	0.04	202.97	911.10	0.22	6.61	(1,5)	28.776	-0.873

TABLE 5.23 REGRESSION ANALYSIS BETWEEN NITROGEN OXIDES AND ODOMETER FOR CALIFORNIA MEDIUM-DUTY GASOLINE-POWERED TRUCKS

Model Year Group	Sample Size	r^2	Mean Square for Regression	Mean Square for Residual	F-value		(DF_1, DF_2)	Intercept (gm/mile)	Slope (gm/mile per 1,000 mile Driven)
					Calculated	95% level			
pre 69	4	0.17	0.99	2.38	0.42	18.51	(1,2)	9.401	-0.047
69-71	7	0.006	0.15	4.84	0.03	6.61	(1,5)	5.367	0.006
72	3	0.19	0.04	0.18	0.23	161	(1,1)	4.771	-0.011
73-74	9	0.0004	0.02	6.30	0.003	5.59	(1,7)	5.492	0.003
75-76	30	0.03	3.95	4.14	0.95	4.20	(1,28)	2.883	0.020
77	15	0.07	2.99	3.22	0.93	4.67	(1,13)	3.901	0.027
78-80	7	0.76	1.22	0.08	14.97*	6.61	(1,5)	2.794	-0.068

*Significant at the 95% level

Of the residual error E is normally distributed with mean zero and variance σ^2 then we can use the F-value for the analysis of variance for the regression to test to see if the coefficient d (deterioration factor) is significantly different from zero. Even if ε is not normally distributed, but the residual is independent with respect to the emission levels a large F-value could indicate that d was significantly different from zero at the 95% level. This only happened in six cases:

1. LDGV hydrocarbon, 75-76, b = 0.51, d = 0.021, F = 39.41 with (1,500) degrees of freedom. 7.3% of the variation was explained, (estimated over the range of 12 miles to 88,860 miles).

2. LDGV, hydrocarbon, 77-79, b = 0.32, d = 0.021, F = 9.16 with (1,61) degrees of freedom. 13.1% of the variation was explained, (estimated over the range of 1,319 miles to 30,037 miles).

3. LDGV, carbon monoxide, 75-76, b = 7.76, d = 0.16, F = 23.05 with (1,500) degrees of freedom. 5.1% of the variation was explained, (estimated over the range of 12 miles to 88,860 miles).

4. LDGV, nitrogen dioxide, 75-76, b = 1.99, d = 0.0079, F = 9.63 with (1,500) degrees of freedom. 1.9% of the variation was explained, (estimated over the range of 12 miles to 88,860 miles).

5. $LDGT_1$, hydrocarbon, 75, b = 0.727, d = 0.137, F = 6.62 with (1,29) degrees of freedom. 19% of the variation was explained, (estimated over the range of 1,857 miles to 84,866 miles).

6. $LDGT_2$, nitrogen dioxide, 78-80, b = 2.794, d = -0.068, F = 14.97 with (1,5) degrees of freedom. 76% of the variation was explained, (estimated over the range of 2,054 miles to 20,585 miles).

Case six should be rejected because of sample size (only 7 vehicles). The negative intercept in case five would indicate that the linear model should not be extended outside of the mileage range. The percent variation explained by the other four cases is noise level. Thus it could be said that a linear model to describe emissions using odometer mileage ratings is not appropriate for this data.